HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI

Climate Change and Biodiversity in Commercial Forests – Forest Owners' Willingness to Adopt Forest Management Practices

Miikka Husa
Master's thesis
Environmental and Resource Economics
Department of Economics and Management
University of Helsinki
January 2021

HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI

Tiedekunta – Fakultet – Faculty	Koulutusohjelma – Utbildingsprogram – Degree Programme
Faculty of Agriculture and Forestry	Master's Programme in Agricultural, Environmental and Resource Economics

Tekijä – Författare – Author

Miikka Husa

Työn nimi – Arbetets titel – Title

Climate Change and Biodiversity in Commercial Forests – Forest Owners' Willingness to Adopt Forest Management Practices

Oppiaine/Opintosuunta – Läroämne/Studieinriktning – Subject/Study track

Environmental and Natural Resource Economics

Työn laji – Arbetets art – Level	Aika – Datum – Month and year	Sivumäärä – Sidoantal – Number of pages
Master's Thesis	21.1.2021	42

Tiivistelmä – Referat – Abstract

Climate change and the biodiversity loss have created a need to change forest management in commercial forests. Carbon sequestration, climate change adaptation, and biodiversity conservation can be promoted in commercial forests through various measures, and this thesis examines what factors affect non-industrial private forest (NIPF) owners' willingness to adopt such forest management practices. Additionally, the aim was to examine whether these factors vary among different measures. A systematic literature review was conducted to summarize previous research on the subject and to serve as reference for an empirical analysis. In the empirical part of the study, survey data of 405 Finnish NIPF owners was utilized to establish binary logistic regression models for forest owners' willingness to adopt 13 distinct forest management practices. In the empirical analysis statistically significant factors varied among assessed forest management practices, although some patterns were recognized. The most striking consistencies were found concerning older forest owners reluctance towards deadwood in general, and positive effect of environmental motivation in willingness to adopt variety of measures, as long as they do not conflict with biodiversity. Overall, the results imply that the diversity of NIPF owners concerns also their stances on various forest management practices, and they are not indifferent in terms of what forest management practices they are willing to adopt. Thus, when designing and implementing policies and advisory services aiming to promote carbon sequestration, climate change adaptation, or biodiversity protection in commercial forests, policy makers should take into account forest owners' heterogenous preferences regarding different forest management practices.

Avainsanat – Nyckelord – Keywords

Non-industrial private forest owners, carbon sequestration, climate change adaptation, biodiversity, commercial forests, forest management

Ohjaaja tai ohjaajat – Handledare – Supervisor or supervisors

Anna-Kaisa Kosenius

Säilytyspaikka – Förvaringställe – Where deposited

Helda, e-thesis

Muita tietoja – Övriga uppgifter – Additional information

Thesis work is conducted as part of the research project Integrated Biodiversity Conservation and Carbon Sequestration in the Changing Environment (IBC-Carbon)

HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI

Tiedekunta – Fakultet – Faculty	Koulutusohjelma – Utbildingsprogram – Degree Programme
Maatalous-metsätieteellinen tiedekunta	Maatalous-, ympäristö-, ja luonnonvaraekonomian maisteriohjelma

Tekijä – Författare – Author

Miikka Husa

Työn nimi – Arbetets titel – Title

Ilmastonmuutos ja monimuotoisuus talousmetsissä – Metsänomistajien halukkuus omaksua metsänkäsittelytapoja

Oppiaine/Opintosuunta – Läroämne/Studieinriktning – Subject/Study track

Ympäristö- ja luonnonvaraekonomia

Työn laji – Arbetets art – Level	Aika – Datum – Month and year	Sivumäärä – Sidoantal – Number of pages
Pro Gradu	21.1.2021	42

Tiivistelmä – Referat – Abstract

Ilmastonmuutos ja luonnon monimuotoisuuden heikkeneminen ovat synnyttäneet tarpeen muuttaa talousmetsien hoitoa. Hiilensidontaa, ilmastonmuutokseen sopeutumista ja luonnon monimuotoisuuden suojelua voidaan edistää talousmetsissä monilla eri metsänkäsittelytavoilla. Tässä työssä tutkittiin, mitkä tekijät vaikuttavat yksityismetsänomistajien halukkuuteen toteuttaa näitä metsänkäsittelytapoja. Lisäksi tarkasteltiin, miten nämä tekijät eroavat eri metsänkäsittelytapojen välillä. Systemaattisen kirjallisuuskatsauksen avulla kartoitettiin aiempi tutkimustieto aiheesta ja taustoitettiin tutkielman empiiristä osiota. Tutkielman empiirisessä osiossa hyödynnettiin kyselyaineistoa 405 suomalaisesta yksityismetsänomistajasta ja tutkittiin metsänomistajien halukkuutta omaksua 13 erillistä metsänkäsittelytapaa binääristen logististen regressiomallien avulla. Regressionanalyysin tulokset osoittivat, että tilastollisesti merkitsevät metsänkäsittelytapojen omaksumishalukkuuteen vaikuttavat tekijät vaihtelivat eri metsänkäsittelytapojen välillä, mutta joitakin yhdenmukaisuuksia tunnistettiin. Erityisesti esiin nousivat metsänomistajan korkean iän yhteys haluttomuuteen lisätä lahopuun määrää metsissä ja metsänomistuksen ympäristömotivaation myönteinen vaikutus lukuisten sellaisten metsänkäsittelytapojen omaksumishalukkuuteen, jotka eivät olleet ristiriidassa monimuotoisuuden suojelun kanssa. Yleisesti tulokset osoittavat, että yksityismetsänomistajat ovat heterogeenisiä suhtautumisessa eri metsänkäsittelytapoihin. Näin ollen hiilensidontaa, ilmastonmuutokseen sopeutumista, ja monimuotoisuutta edistävien kannustinjärjestelmien suunnittelussa tulisi huomioida metsänomistajien erilaiset näkemykset metsänkäsittelytavoista, joilla näitä asioita pyritään edistämään.

Avainsanat – Nyckelord – Keywords

Yksityismetsänomistajat, hiilensidonta, ilmastonmuutokseen sopeutuminen, monimuotoisuus, metsätalous, metsänhoito

Ohjaaja tai ohjaajat – Handledare – Supervisor or supervisors

Anna-Kaisa Kosenius

Säilytyspaikka – Förvaringställe – Where deposited

Helda, e-thesis

Muita tietoja – Övriga uppgifter – Additional information

Tutkielma toteutettiin osana Metsäluonnon monimuotoisuuden suojelu ja hiilen sitominen muuttuvassa ympäristössä (IBC-Carbon) -projektia

HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI

Table of Contents

1 Introduction

Climate change and biodiversity crisis have created a need to change forest management in commercial forests. In Finland, climate change is likely to increase forest growth, but also the risk of abiotic and biotic forest damages (Kellomäki et al., 2018; Venäläinen et al., 2020). Due to warmer and drier summers, drought, forest fires, pest invasions are likely to become more common, while milder and wetter winters increase risk of wind- and snow damages, and pathogens (Venäläinen et al., 2020). Adaptative measures and increased resilience are needed to respond to changing growth conditions and increased risk of abiotic and biotic hazards. Furthermore, forests play an important role in climate change mitigation due to their ability to sequestrate and store carbon. Biodiversity is inseparably connected to climate change adaptation and mitigation in forests, since biodiversity contributes to ecosystem functioning and provision of crucial forest ecosystem services (Brockerhoff et al., 2017). Promoting biodiversity through improving degraded habitats of commercial forests can contribute to reducing anthropogenic net emissions and increasing resilience towards climate change (Thompson et al., 2009).

Carbon sequestration, climate change adaptation, and biodiversity conservation can be promoted in commercial forests through various forest management practices. Depending on the applied forest management practice, their impacts on carbon sequestration, climate change adaptation, and biodiversity can be both consistent or conflicting (Felton et al., 2016). For example, extending rotation period contributes both to climate change mitigation and biodiversity, since it promotes carbon sequestration, increased amount of deadwood and increased proportion of old-growth forests (Ranius et al., 2003; Koskela et al., 2007; Felton et al., 2016), while favoring a mixture of deciduous tree species in coniferous forests instead of monocultures promotes not only biodiversity, but also climate change adaptation through increased resilience towards wind-damage, pest invasions, and pathogens (Felton et al., 2016). Conflicting impacts occur for in e.g. shortened rotation period, which aims for climate change adaptation but is expected to have negative implications for biodiversity (Ranius et al., 2003; Mönkkönen et al., 2014; Felton et al., 2016). Since these alternative forest management practices have varying impacts on carbon sequestration, climate change adaptation, and biodiversity conservation, it is challenging to classify forest management practices based on which objective they primarily aim for. The purpose of this thesis is to assess non-industrial private forest (NIPF) owner's willingness to adopt various forest management practices, instead of examining their attitudes towards climate change or biodiversity in general. Therefore, forest management practices promoting carbon sequestration, climate change adaptation, and biodiversity conservation are assessed as a single entity in this study.

Non-industrial private forest (NIPF) owners play an important role in carbon sequestration, climate change adaption and biodiversity protection, since a large proportion of forestland is under their ownership. For example, in both Europe and the US, NIPF owners own approximately half of all forestland (Forest Europe, 2015; Butler et al., 2016). Even though there is extensive literature on forest owner management actions, most of these studies that aim to predict private forest owners' participation in carbon sequestration, climate change adaptation, or biodiversity protection assess these issues at a very general level. Especially in the U.S., forest owners' attitudes towards carbon sequestration, willingness to participate in carbon trading, or interest in wildlife habitat management have been popular research topics (e.g. Thompson & Hansen, 2012; Markowski-Lindsay et al., 2011; Joshi & Arano, 2009). However, forest owners' choice to adopt distinct forest management practices that aim to promote carbon sequestration, climate change adaptation or biodiversity protection in commercial forests have received little attention. A wide range of studies have shown that NIPF owners are a diverse group, and in addition to timber production they have other motivations and objectives for their ownership (e.g. Ficko et al., 2019). Reflecting on the diversity of NIPF owners, one could hypothesize that owners are not indifferent in terms of which forest management practices would be applied in their forests.

Finland is the most forested country in Europe, with 86% of land covered by forests. Most forestland in Finland is under the ownership of NIPF owners (52%), followed by state (35%), corporations (9%), and municipalities, church and communities (6%). From the perspective of commercial forestry and biodiversity protection, the significance of NIPF owners in Finland is further emphasized by the fact that state owned forests are centered in Northern Finland, while more productive southern forests are mostly under NIPF ownership. Since the majority of protected forests are state owned, protected forests are heavily concentrated in Northern Finland. (Peltola et al., 2019). However, southern forests are currently especially important in terms of biodiversity, since the majority of endangered forest species occur primarily in southern forest habitats. Furthermore, the reasons for endangerment are primarily forestry related: changes in tree species proportions, loss of old-growth forests, lack of deadwood, and absence of forest fires. (Hyvärinen et al., 2019)

Regarding biodiversity conservation, "habitats of special importance" defined by the Finnish Forest Act (1093/1996) and "protected natural habitats" referred to in the Nature Conservation Act (1096/1996) are excluded from forestry by legislation. Otherwise, biodiversity protection in Finland is based on voluntariness. A state-owned organization Tapio provides best practice recommendations for forest management in Finland. These guidelines provide a set of economically, ecologically, socially, and culturally sustainable alternatives for forest management (Äijälä et al., 2019). In addition to guidelines for commercial forestry and timber trading, Tapio provides detailed instructions for nature management in commercial forests, game habitat management, and water protection (Saaristo & Vanhatalo, 2019; Linden et al., 2019; Joensuu et al., 2019). Tapio recommendations for forest management emphasize the importance of forest owner's individual objectives; for example, forest owners with environmental motivations may choose to adopt environmentally sustainable forest management beyond requirements of legislation.

Forest certification, METSO forest conservation program, and Sustainable Forestry Subsidy (KEMERA) subsidies provide incentives for forest owners to promote biodiversity in their forests beyond requirements of legislation. Forest certification eases timber trading and can increase the stumpage price, due to the demand of certified wood products in the markets. Additionally, certification provides impartial external validation for sustainability of forest management (Rametsteiner & Simula, 2003). In Finland, approximately 90% of forests are PEFC certified, and 10% are FSC certified (PEFC Suomi, 2019; FSC Suomi, 2019). Certification requires adopting measures such as deadwood retention, broadleaved mixtures in coniferous forests and retention trees (PEFC Suomi, 2014; FSC Suomi, 2011). To promote biodiversity protection, Finland has launched METSO, a forest biodiversity program for Southern Finland. The program is based on voluntariness; forest owners can offer their ecologically valuable stands for temporary or permanent conservation, and forest owners are compensated based on the value of timber at a protected site (METSO, 2019). Forest owners can also apply for Sustainable Forestry Subsidy (KEMERA) for conducting nature management practices in their forests. The subsidy can be granted for e.g. habitat restoration, prescribed burning and invasive species control (Kestävän metsätalouden määraikainen rahoituslaki 34/2015). To promote carbon sequestration in forests, the Finnish government removed nutrient deficiency requirements concerning the KEMERA subsidy for ash fertilization in 2020 (Ministry of Agriculture and Forestry, 2020).

Compared to the extent of forest biodiversity protection policies in Finland, measures promoting carbon sequestration and climate change adaptation in forests have been minor. However, policymakers have declared ambitions to promote such policies in the near future. Guidelines for climate change adaptation have been included in the most recent publication of Tapio recommendations, and Finnish forest strategy 2025 specifies need to produce knowledge on climate change mitigation and adaptation to further consideration of these issues in decision making (Äijälä et al., 2019; Ministry of Agriculture and Forestry, 2019). Finland’s current government program includes extensive set of measures related to enforcing carbon sequestration in private forests: developing policy tools and incentives to promote carbon sequestration in forests, promoting diverse forest management practices concerning climate targets, and revising Tapio recommendations and KEMERA subsidies considering carbon sequestration and biodiversity protection (Valtioneuvosto, 2019). Since these policies are primarily based on voluntariness, knowledge of forest owners diverse attitudes, views, and objectives is essential when designing and implementing such policies.

This thesis assesses NIPF owners willingness to adopt distinct forest management practices that promote carbon sequestration, climate change adaptation, and biodiversity protection in commercial forests. The following research questions are examined:

1. What factors affect NIPF owners’ willingness to adopt forest management practices that aim promote carbon sequestration, climate change adaptation, or biodiversity?

2. Do these factors differ among distinct forest management practices?

To answer these questions, a systematic literature review was conducted, and an empirical analysis was performed using survey data of 405 Finnish non-industrial private forest owners. Following set of forest management practices were assessed in the empirical analysis of this study: lighter managed buffer zones around important habitats and/or conservation areas, leaving at least 10 m3 of deadwood per hectare when logging, mixed tree species in coniferous forest (at least one fifth of birches or other deciduous trees), leaving at least 5% of the logging volume as a stand (over 20 cm in diameter), leaving wind-felled trees to the ground according to the maximum limit determined by the law of forest damage, lengthening the rotation period by a quarter, leaving all logging residues at the terrain, saving habitats for game (e.g. thickets) at thinnings and tending of seedling stands, continuous cover forestry, increasing growing density of the stand, and fertilizing low-yielding areas, shortening the rotation period by a quarter, and forest regeneration with southern seedlings that can adapt better to warming climate. The set of forest management practices are based on workshop organized for forest professionals and researchers by IBC-CARBON project in November 2018.

The remainder of this thesis is organized as follows: in Chapter 2 theoretical background of private forest owner behavior is established, Chapter 3 presents a systematic literature review on NIPF owners' willingness to adopt carbon sequestration and biodiversity enhancing forest management practices, Chapter 4 summarizes statistical analysis, results are discussed in Chapter 5, and Chapter 6 concludes the thesis

2 Theoretical Background

Forest owner management decisions are assumed to be based on utility-maximizing behavior. For forest owner, forest produces both income through timber sales that can be used to consume other goods and services, and nontimber forest outputs (recreation, aesthetic values, biodiversity, carbon sequestration etc.). Thus, forest owners make management decisions incorporating both timber and nontimber objectives. (Binkley, 1981) Individual forest management practices considered in this study generally affect timber production, biodiversity, carbon sequestration, climate change adaptation and other forest amenities altogether. Forest owners are assumed to choose whether or not to apply some forest management practice considering all these amenities in order to maximize utility. The utility index is unobservable, but the decision to engage in forest management is determined by a set of observable factors (Joshi & Arano, 2009). Previous studies have shown that forest owners' choice to adopt forest management practices that aim to promote carbon sequestration, climate change adaptation, and biodiversity conservation is affected by owner characteristics (e.g. Juutinen et al., 2020; Khanal et al., 2017; Matta et al., 2009; Joa & Schraml, 2020), owner' motivations and objectives (e.g. Khanal et al., 2017; Kline et al., 2000), site-specific factors (e.g. Mäntymaa et al. 2018), and previous management (e.g. Juutinen et al., 2020). Following Joshi & Arano (2009), the determinants of adopting forest management practices can be assumed to be a vector of sociodemographic characteristics, site-specific characteristics, owner objectives, and previous management. The model for forest owner management behavior could be expressed as follows:

$$U_i = f\{TN(INV)|S_i, F_i, O_i, M_i\}$$

where U_i equals landowner utility derived by forest owner *i* investing in forest management activities; *TN* is a production function for timber and nontimber output consumed by forest owner; and *INV* represents investments in forest management activities. Investments in forest management activities are assumed to be determined by sociodemographic characteristics S_i, forest site characteristics F_i, owner motivations and objectives O_i, and previous management actions M_i. U_i and TN are unobservable, but *INV* can be observed by whether or not forest owner is willing to adopt a certain forest management practice. Since *INV* is determined by S_i, F_i, O_i, M_i, the econometric model represents indirect utility:

$$INV = f(S_i, F_i, O_i, M_i) + \varepsilon_i$$

where ε_i equals random error term.

3 Literature review

Literature review was conducted to discover what factors have been found to affect forest owners' willingness to adopt forest management practices by previous research. The findings of the literature review present the extent of previous research on the subject, discover previous research's contribution to research questions of this thesis, and establish background for empirical analysis. The scope of the literature review was restricted to studies that provided some analysis on factors affecting NIPF owners choice to adopt forest management practices. Definition of forest management practices was considered as a fundamental criterion for inclusion; studies assessing NIPF owners willingness to participate in carbon sequestration, climate change adaptation, or biodiversity protection were excluded in case forest management practices were not defined. In order to include all relevant literature, a systematic approach was applied for article search process.

3.1 Systematic search process

The articles were searched for in SCOPUS online database. Search terms representing NIPF owners (e.g. forest owner, land owner) were combined with keywords related to forest management practices promoting carbon sequestration, climate change adaptation, or biodiversity. Search terms related to forest management practices included keywords such as continuous cover, delay, and fertilization. In order to include all relevant literature, also universal keywords such as carbon and biodiversity were combined with forest owner terms. The procedure included 54 combinations of search terms, yielding 2569 results in total. Complete list of search terms can be found in appendix 1. The results were initially screened for relevance based on title and abstract. Majority of results could be excluded from the final sample already at this stage. Many studies were from the field of natural sciences, or had otherwise clearly irrelevant scope. Studies that seemingly included private forest owners' point of view, and assessment of carbon sequestration, climate change adaptation, or biodiversity promoting forest management were left for further evaluation. After the first screening round and removing of duplicates, 161 articles remained for second screening phase.

Next, the remaining papers were screened based on full article. At this stage, most of the excluded articles were left out due to absence of forest owner's point of view or definition forest management practices. After excluding irrelevant articles at the second stage, 47 articles remained. These articles were tabulated and compared in terms of applied methodology, data, and forest management practices assessed in the study. At this final screening stage, articles that did not provide sufficient analysis on the forest owners' choice of forest management practices were excluded. Finally, a sample of 20 articles was obtained

3.2 Sample of articles

Out of the 20 articles, 6 studies were conducted in the U.S and the rest of the studies were European. Six studies were conducted in Finland, four in Sweden, and one in Denmark, Germany, Georgia and Belgium each. Majority of U.S. studies were conducted at state-level. Due to geographical variation, the forestry context in which selected forest management practices were applied needs to be acknowledged. Articles in the final sample are from 2000-2020. The general characteristics of studies are presented in Table 1.

Out of 20 articles, 17 applied quantitative methodology and three were qualitative. The extent of sample studies varies significantly, the most extensive quantitative study has 1264 respondents, while the least extensive had 253. Sample size of qualitative studies varied between 15 and 33. Quantitative studies can be characterized by four different statistical approaches; measuring choice of forest management practices as dependent variables, predicting payments for ecosystem services (PES) program participation, comparing differences among forest owner groups, and assessing management practices as independent variables in factor analysis or principal component analysis (PCA). The two first mentioned approaches applied similar statistical methodology; adoption of management practices or program participation was predicted using regression analysis. Studies with comparative approach commonly applied descriptive statistical methodology and chi-square tests. Qualitative studies were based on face-to-face and telephone interviews.

Table 1
Overview of articles

#	Author(s)	Year	Region	n	How is choice of measure assessed?	Included in PES program	# forest management practices assessed
1	Joa, B., Schraml, U.	2020	Germany	419	Dependent variable		2
2	Juutinen, A., Tolvanen, A., Koskela, T.	2020	Finland	708/1035	Dependent variable		3
3	Kang, M.J., Siry, J.P., Colson, G., Ferreira, S.	2019	Georgia	253	Program participation	x	1
4	Danley, B.	2019	Sweden	1231	Comparison between groups		1
5	Mäntymaa, E., Juutinen, A., Tyrväinen, L., Karhu, J., Kurttila, M.	2018	Finland	476	Program participation	x	1
6	Karppinen, H., Hänninen, M., Valsta, L.	2018	Finland	15	Qualitative		2
7	Kooistra, C.M., Moseley, C., Huber-Stearns, H., Rosenberg, S.	2018	USA, Oregon	441	Dependent variable		1
8	Pynnönen, S., Paloniemi, R., Hujala, T.	2018	Finland	298	Variables in factor analysis		3
9	Danley, B.	2018	Sweden	1264	Dependent variable		1
10	Khanal, P.N., Grebner, D.L., Munn, I.A., Grado, S.C., Grala, R.K., Henderson, J.E.	2017	USA, Southern	735	Program participation	x	1
11	Vedel, S.E., Jacobsen, J.B., Thorsen, B.J.	2015	Denmark	283	Program participation	x	4
12	Kim, T., Langpap, C.	2015	USA, Western	513	Dependent variable		1
13	Hallikainen, V., Hyppönen, M., Pernu, L., Puoskari, J.	2010	Finland	525	Variables in factor analysis		5
14	Van Herzele, A., Van Gossum, P.	2009	Belgium	276	Dependent variable		1
15	Matta, J.R., Alavalapati, J.R.R., Mercer, D.E.	2009	USA, Florida	400	Program participation	x	2
16	Horne, P.	2006	Finland	1240	Program participation	x	2
17	Hysing, E., Olsson, J.	2005	Sweden	16	Qualitative		1
18	Gotmark, F., Soderlundh, H., Thorell, M.	2000	Sweden	33	Qualitative		1
19	Kline, J.D., Alig, R.J., Johnson, R.L.	2000a	USA, Pacific Northwest	403	Program participation		1
20	Kline, J.D., Alig, R.J., Johnson, R.L.	2000b	USA, Pacific Northwest	1004	Program participation		1

Forest owners' choice to apply forest management practices was studied by considering individual management practices as dependent variables in 6 studies. Number of management practices assessed in each study varied between 1 to 3. These studies applied a variety of regression models such as random parameter logit models, probit models, and OLS regressions to predict the probability of forest owner to choose certain management practices. In these studies principal component analysis (PCA) was also a commonly applied method to condense dimensions of forest owner motivations and beliefs. These studies didn't generally perform analysis on forest owners' compensation claims.

In 8 studies, choice of forest management practices was included in various payments for ecosystem services schemes. The methodological approach of predicting the probability of program participation in these studies was similar to studies that assessed choice of forest management practices as dependent variables, and different regression analysis were applied. The theoretical basis of NIPF owners' management decisions are often assumed to be based on individual utility-maximizing behavior (Kline et al., 2000), and majority of these studies applied non-market valuation techniques to discover sufficient compensation payments that NIPF owners would be willing to accept for adopting carbon sequestration and biodiversity promoting forest management practices. In addition to slightly different starting point in analyzing choice of measures, analysis of compensation claims is a distinctive factor in comparison to studies regarding forest management practices as dependent variables. In this literature review results concerning compensation claims are not reviewed.

Danley (2019) applied a comparative approach, assessing whether different forest owner typologies differ in terms of adopting forest management practices in question. One-tailed two sample z-tests for differences of proportion were used to examine differences among owner groups. Pynnönen et al. (2018) and Hallikainen et al. (2010) applied distinct forest management practices as independent variables in factor analysis and principal component analysis, respectively. Instead of assessing forest owners' choice of forest management practices, both studies aim to identify different forest management styles based on forest owners' views on these management practices, among other variables. Even though forest owners' choice to apply these forest management practices is not directly assessed in these studies, they provide insight how adoption of these practices is linked to different forest management styles.

Three qualitative studies were included in the literature review sample. These studies applied face-to-face (Karppinen et al., 2018; Hysing & Olson, 2005) and telephone interviews (Götmark et al., 2000) to assess forest owners views on carbon storage in their forests (Karppinen et al., 2018), biodiversity protection (Hysing & Olsson, 2005) and establishing buffer zones around forest reserves

(Götmark et al., 2000). Qualitative studies provided insight on forest owners' views towards some distinct forest management practices.

It is also important to note, that despite all articles included in the literature review provide some insight on forest owners' choice to adopt forest management practices, there is considerable variation among approaches to study this issue. Some studies assess the previous or intended management decisions, while others focus on general attitudes, views or beliefs towards selected forest management practices. Additionally, studies differ in terms of how adoption of forest management practices are measured. For example, Juutinen et al. (2020) predict forest owners' future intentions for forest management by studying what proportion of their property they intend to allocate under different management practices, while e.g. Khanal et al. (2017) and Matta et al. (2009) study the probability of adoption on forest management practices through participation in PES schemes.

Table 2 presents a summary of what forest management practices have been assessed. Majority of studies assessed only one measure, while others included 2-5 different management practices. Most commonly studied forest management practices in the sample were leaving unmanaged areas (6) and delayed harvest (6), followed by riparian buffers (5), deadwood retention (4), retention trees (4), broadleaved mixtures (3), continuous-cover forestry (2), fertilization (2), shortened rotation (1) and buffer zones around protected areas (1).

Table 2

Forest management practices assessed

Forest management practice		Article #																			
	Count	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Unmanaged areas	6	x							x	x		x		x			x				
Delayed harvest	6		x			x	x				x					x					x
Riparian buffers	5			x				x						x		x				x	
Deadwood retention	4	x										x		x				x			
Retention trees	4				x				x			x		x							
Broadleaved mixtures	3											x		x	x						
Continuous-cover forestry	2		x						x												
Fertilization	2						x						x								
Shortened rotation	1		x																		
Buffer zones around protected areas	1																		x		
Count		2	3	1	1	1	2	1	3	1	1	4	1	5	1	2	1	1	1	1	1

3.3 Factors affecting choice to adopt forest management practices

3.3.1 Owner characteristics

In terms of sociodemographic factors, age, gender, income, residence, education, occupation, and membership in forest owners’ association affected willingness to adopt forest management practices. Increase in forest owner’s age generally reduces the probability of participating in PES schemes requiring delaying harvest (Khanal et al., 2017; Matta et al., 2009). A somewhat contrary finding was made by Juutinen et al. (2020), that increase in forest owner’s age had a positive effect on the share of forest allocated to long rotation management. Age also increased the probability to allocate forest to short rotation management and traditional even-aged forestry. Regarding uneven-aged forestry, increase in age had a negative effect. Uneven-aged forestry was also more common among women. (Juutinen et al., 2020) Matta et al. (2009) found that forest owners who live close to their properties were more likely to participate in PES scheme requiring delayed harvest, riparian buffer zones and conducting prescribed burning.

Many studies find that highly educated forest owners are more willing to adopt suggested forest management practices and to participate in PES schemes. Such findings have been made concerning delayed harvest (Matta et al. 2009; Kline et al., 2000), converting monocultures into mixed broadleaved stands (Van Herzele & Van Gossum, 2009), and deadwood retention (Joa & Schraml, 2020). Juutinen et al. (2020) found that highly educated forest owners were less likely to allocate forest to short rotation management. The authors suggest that highly educated forest owners tend to value forest amenities higher and consider short rotation management the most intensive management style, and thus avoid short rotation management. Agricultural entrepreneurs preferred traditional and long rotation management (Juutinen et al., 2020). Kim & Langpap (2015) found, that owners whose occupation is related to logging, owners with primary timber production objective and owners whose sites are suitable for timber production required higher subsidies for fertilization of forests compared to other forest owners. Membership in forest owners’ association decreased the probability to leave unmanaged areas in forests, both voluntarily or through certification (Danley, 2018).

The studies included in literature review found consistent results on effect of forest owner’s income on adoption of management practices and PES program participation. Higher income tends to increase the probability of program participation and adopting suggested forest management practices. The effect was found concerning delayed harvest (Khanal et al, 2017; Matta et al., 2009;

Kline et al., 2000) and riparian buffers (Matta et al., 2009). Concerning importance of forestry-related income, Kline et al. (2000) found that owners who were more dependent on timber sales were less likely to delay harvest.

In addition to sociodemographic factors, the effect of forest owners' attitudinal aspects on adoption of forest management practices and program participation were often somehow assessed. The effect of beliefs, attitudes, perceptions and knowledge were often found as statistically significant variables affecting willingness to adopt forest management practices. For example, perceived benefits of deadwood retention (Joa & Schraml, 2020), and knowledge on carbon sequestration (Khanal et al., 2017) increase the probability to adopt suggested forest management practices. Concerning deadwood retention, Joa et al. (2020) also concluded that forest owners who perceived deadwood retention as a threat, were less likely to adopt deadwood retention practices. They also conducted a principal component analysis on perceptions of integrated forest management, a management style that seeks to integrate biodiversity promoting forestry practices in commercial forestry. The authors found that owners who shared the view of integrated forest management practices were more approving towards deadwood retention. Juutinen et al. (2020) examined attitudinal aspects through very specific statements. Owners who considered, that forests are well managed for recreation purposes or biomass production, favored short rotation management. Owners who agreed that Finnish forests are well managed from the perspective of timber production, biodiversity, or climate change mitigation, were more likely to favor traditional management instead of uneven-aged management. Overall, there seems to be evidence that forest owners' positive attitudes towards nature, biodiversity and carbon sequestration are reflected in their willingness to undertake forest management activities that promote these issues.

Kang et al. (2019) and Kooistra et al. (2018) made more novel findings concerning attitudinal aspects and riparian buffer zones. Kang et al. (2019) found that more risk-averse owners were more likely to participate in PES programs, and also had lower compensation claims for adopting wider riparian buffer zones. Kooistra et al. (2018) found that political orientation was the most significant belief-related determinant concerning attitudes towards wider buffer zones. The authors suggest that political attitudes stood out due to lack of knowledge concerning the ecological outcomes of riparian buffer zone regulation.

3.3.2 Owner motivations and objectives

Establishing forest owner typologies based on ownership motivations and objectives in common tool in studies examining provision of public goods through forestry or promoting specific forest management practices (Ficko et al., 2019). Such approach was also commonly applied in studies included in this literature review. A recurring finding is that recreational and multiobjective objectives and motivations tend to increase the probability of adopting suggested forest management. The effect has been found concerning at least delayed harvest (Khanal et al., 2017; Kline et al., 2000) and riparian buffer zones (Kline et al., 2000). Kline et al. (2000) also noted that despite forest owners with timber production objective were demanded highest compensation for wide riparian buffer zones, their participation is important since they tend to own larger stands.

3.3.3 Forest site characteristics and management

Concerning site-specific factors, the effect of forest holding size stands out in literature review sample. Increase in property size has been found to increase the probability of delaying harvest (Khanal et al., 2017; Mäntymaa et al. 2018), leave unmanaged areas (Danley, 2018), and convert monocultures to mixed broadleaved stands (Van Herzele & Van Gossum, 2009). Only Kline et al. (2000a, 2000b) found controversial results on the effect of forest property size, regarding delayed harvest and riparian buffer zones. The authors suggest that increasing marginal returns of forestry explain this effect (Kline et al., 2000). Concerning the effect of forest site suitability for timber production, results are comprehensible. Poor stand characteristics in terms of timber production seem to have a positive effect on forest owner's probability to adopt carbon sequestration and biodiversity promoting forest management practices (Matta et al., 2009; Kim & Langpap., 2015; Joa & Schraml, 2020).

Both previous and intended forestry-related decisions have been found to affect forest owners' stance on suggested forest management practices. Concerning previous management actions, owners who had applied natural regeneration were more likely to apply uneven-aged management. Regarding short rotation management, previous clearcutting had a positive effect and tending had a negative effect. Previous firewood harvesting decreased the probability to allocate forestland to long rotation management. (Juutinen et al., 2020) Probability to participate in PES program requiring temporary protection is positively affected by existing set-aside areas (Layton & Siikamäki, 2009) and previous clearcuttings (Mäntymaa et al., 2018). Kline et al. (2000) found a somewhat contrary result regarding delayed harvest, forest owners who intend to clearcut in the future were less willing to adopt this practice.

3.3.4 Program characteristics

Program characteristics are important factors affecting forest owners' willingness to participate. In addition to strictness of requirements, the way program is organized affects forest owners' willingness to participate (and their compensation claims). Willingness to participate seems to decrease as duration of the contract increases (Horne, 2006; Kang et al., 2019). Willingness to participate also decreases when forest management plan is required (Khanal et al., 2017). Horne (2006) also found that forest owners preferred protection of small patches instead of establishing a strict nature reserves, and were more willing to participate if they were initiators of the contract instead of forest organization, environmental organization or conservation trust. According to Götmark et al. (2000), forest owners prefer compensation programs for partial protection to state buying the land, since forest owners had strong emotional attachment to their land and had bequest motives. These findings suggest that forest owners wish to dictate their land and keep hold of their ownership as much as possible when considering PES program participation.

Predictably, monetary compensation for adopting carbon sequestration and biodiversity promoting forest management practices generally increases the willingness to participate such programs. These forest management practices often contradict with timber production, and forest owners demand compensation for potential economic losses. However, forest owners seem to be willing to adopt few forest management practices at some level with very little or no compensation at all. Especially leaving voluntarily unmanaged areas in forest property seems to be common among forest owners (Joa & Schraml, 2020; Danley, 2018; Vedel et al., 2015; Horne, 2006). However, Joa & Schraml (2020) states that most common reason for leaving voluntary set aside areas are unsuitable characteristics for harvesting and poor productivity. Leaving set aside areas based on nature conservation motives was rare (Joa &Schraml, 2020). According to Vedel et al. (2015), Danish forest owners were also willing to accept requirement of 50 % mixture of broadleaved trees in their stands without compensation. Concerning riparian buffer zones, both Matta et al. (2009) and Kang et al. (2019) found that forest owners didn't require any compensation for establishing 100 feet wide buffer zones. For buffer zones 150 and 200 feet wide, compensation was required.

3.3.5 Forest management styles

The methodological approach of Pynnönen et al. (2018) and Hallikainen et al. (2010) differ from other studies in the literature review sample. Both applied dimension reduction methods to classify different forest management styles based on forest owners' views towards various forest management practices, among other variables. Both studies were conducted in Finland, specifically in Lapland (Hallikainen et al., 2010) and North Karelia (Pynnönen et al., 2018). Hallikainen et al. (2010) recognized four different forest management styles based on forest owners opinions on various forest management practices; detailed conservation, intensive forestry, strip cuttings and natural regeneration. Deadwood retention practices, riparian buffer zones and set-aside areas determined detailed conservation forest management style. Natural regeneration style also included biodiversity promoting forest management practices; deciduous trees mixtures, selective cuttings and retained old pines.

Pynnönen et al. (2018) conducted similar factor analysis on forest management styles as Hallikainen et al. (2010). In addition to variables concerning adoption of forest management practices such as obtaining management plan focusing on uneven-aged forestry, leaving retention trees more than required by PEFC certification, preserving selected areas, Pynnönen et al. (2018) included more general variables, such as intention to obtain multiobjective forest management plan, and adopting alternative forest management regimes. Two factors were recognized, "diversifying forest management practices" and "emphasis on nature". Preserving selected areas and leaving retention trees more than required was included in emphasis on nature forest management style, and obtaining forest management plan focusing on uneven-aged forestry was associated with diversifying forest management practices forest management style. Additionally, Pynnönen et al. (2018) conducted factor analysis and clustering based on forest owners objectives. Pynnönen et al. (2018) and Hallikainen et al. (2010) recognized similar groups in their cluster analysis; multiobjective, timber producers, and conservationists/emphasis on nature. The results were consistent, timber producers were the largest owner group followed by multiobjective owners and conservationists. Even though timber production seems to be dominant objective of forest owners, both studies found favorable attitudes towards conservation. According to Hallikainen et al. (2010), forest owners were favorable towards small scale nature conservation, and approximately half of study respondents were ready to accept small losses in forestry income. Pynnönen et al. (2018) stated that large share of forest owners were willing to combine economic and other objectives in forest management, and emphasized importance of policy measures supporting nature management.

3.3.6 Qualitative insights

Karppinen et al. (2018) assessed forest owners' attitudes towards storing carbon in their forests. In general, views towards carbon storage were mostly positive, but compensation was important when considering participation in carbon storing programs. Owners preferred fixed-term contracts or having only some parcels under program at time (Karppinen et al., 2018). These findings seems consistent with studies assessing participation in delayed harvest PES programs, forest owners demand compensation for lost forestry income and prefer shorter fixed term contracts (e.g. Horne, 2006; Kang et al., 2019). Although attitudes towards storing carbon were mostly positive, delaying harvest worried some forest owners, as they were afraid of decaying timber if harvest is postponed (Karppinen et al., 2018). Fertilization was considered acceptable among all forest owner typologies, and many owners had already applied it in their sites. Despite positive attitudes towards fertilization, they found consistent results with Kim & Langpap (2015), that fertilization was considered a costly operation, and monetary subsidies would be needed to adopt it.

Concerning deadwood, Hysing & Olsson (2005) found that majority of forest owners interviewed (13/16) had negative attitudes towards dead wood in forests. Leaving large amounts of dead wood was considered contrary to a well-managed forest, and it was considered to increase the risk of pest invasions and make work and recreation more dangerous. These negative remarks were similar to “hazards and obstacles” component in PCA conducted by Joa & Schraml (2020), but unlike Joa & Schraml (2020), Hysing & Olsson (2005) didn’t report any positive perceptions of deadwood from forest owners.

Götmark et al. (2000) studied forest owners' attitudes towards establishing buffer zones around forest reserves by interviewing 33 forest owners. Two alternatives were studied, compensating forest owners for partial protection within buffer zones, or state buying their land for conservation purposes. Overall, majority of forest owners had negative attitudes towards establishing nature reserves on their lands, but given full economic compensation, majority of owners were neutral or positive towards buffer zones. Compensation for partial protection was also preferred to the state buying the land due to emotional attachment to their land and bequest motives.

3.4 Summary

Based on previous research, sociodemographic variables, attitudinal aspects, owner motivations and objectives, previous management activities, forest site characteristics, compensation, and compensation contract characteristics affect forest owners choice to adopt various forest management practices. Mainly, the effect of these factors was consistent regardless of forest management practice. Sociodemographic variables such as younger age, income, and high education had constant positive effect. Compensation, short contracts, poor site characteristics for timber production, nature-oriented attitudes and non-timber objectives all increased the probability to adopt forest management practices. Compensation was generally required for adopting forest management practices that potentially cause more significant economic disadvantages for forest owners, such as delaying harvest beyond optimal rotation age. Although timber production is the most important objective for most forest owners, there seems to be evidence that forest owners are willing adopt some forest management practices, such as retention trees, broadleaved mixtures, and riparian buffers with little or no compensation (Vedel et al., 2015; Kang et al., 2019; Kline et al., 2000). Although most variables had a consistent effect over various forest management practices, forest owners' attitudes were more polarized concerning some measures. Especially deadwood retention worried some forest owners, and leaving excessive amounts of deadwood was considered contrary to best-practice management guidelines (Joa & Schraml, 2020; Hysing & Olsson, 2005). Reserved attitudes were also recognized concerning delayed harvest (Karppinen et al., 2018).

Based on this literature review, it seems that previous research provides quite comprehensive insight on factors affecting forest owners' willingness to adopt different forest management practices. However, research frames of many studies seem to emphasize the objective that certain forest management aims for. For example, Khanal et al. (2017) study forest owners willingness to delay harvest for additional carbon sequestration, and Matta et al. (2009) discuss willingness to delay harvest to promote biodiversity. Therefore, a question arises whether these studies provide more information on forest owners' views towards these objectives rather than forest management practices applied to achieve it, and whether the results would be different if the emphasis was on another objective but forest management practice remains the same. Additionally, most studies in the literature review sample assess only one forest management practice, and therefore lack comparison between willingness to adopt different forest management practices. In the next section of this thesis the aim is to contribute in filling this research gap by presenting an empirical analysis on forest owners' willingness to adopt 13 distinct forest management practices.

4 Empirical analysis

4.1 Data

The statistical analysis was based on survey data of 405 Finnish NIPF owners. The survey was designed in autumn 2018 and administered in February 2019 by a professional polling company Kantar TNS, using a nation-wide sample of forest owners available in their consumer panel. The data was gathered for the purposes of IBC-Carbon project, that aims to provide decision-supporting tools on optimal forest management in changing climate and securing forest connectivity. A 15-minute survey included questions on characteristics of forest property, motivations of ownership, stated enrollment to a new voluntary based forest conservation program, the stated intention to adopt various forest management practices, previous management, attitudes and perceptions on forest management, and background questions on forest owner characteristics. The survey was conducted in Finnish.

Table 3 presents descriptive statistics of the data compared to nationwide Finnish Forest Owner 2020 survey (FFO 2020) (Karppinen et al., 2020). The respondents of IBC-Carbon forest owner survey were more often female, they were slightly younger on average and more highly educated. Living permanently on their holding was less common in IBC-Carbon survey. The scale of household income was not fully comparable to FFO 2020 reference sample, however it could be noted that share of households with yearly income less than 20 000 € was smaller in Kantar TNS sample, and the share of households with over 100 000 € yearly income was similar in both data sets. Size of forest holding was similar in both studies. Slight bias in IBC-Carbon survey might result from the fact that the sample of forest owners was obtained from Kantar TNS consumer panel. One might fairly presume that consumer panel is biased towards younger individuals and city-dwellers.

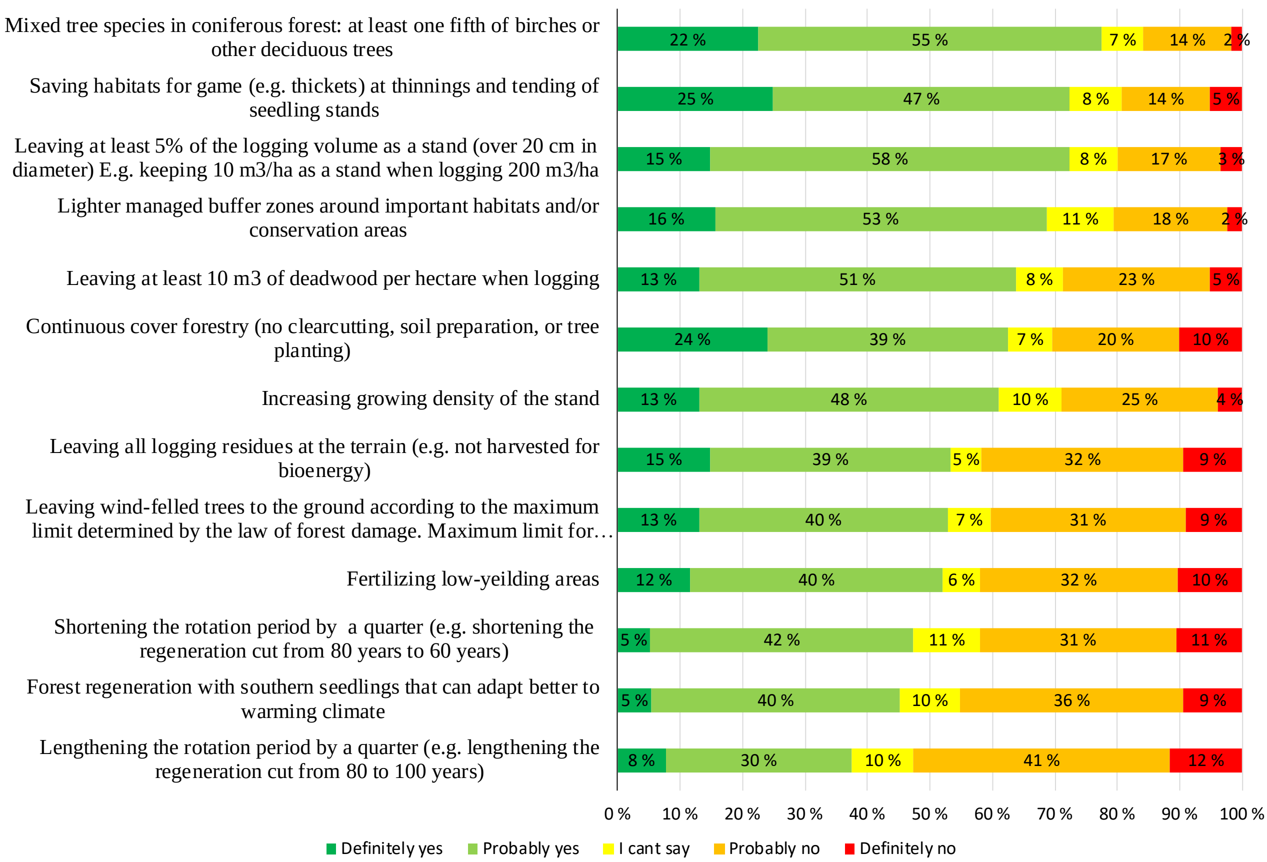
Table 3

Descriptive statistics	Survey (n=405)	Finnish Forest Owner 2020 (n=6542)
Forest owner characteristics		
Gender, %		
Female	36	25
Male	64	75
Age, %		
< 45	20	12
45-64	31	37
> 65	49	50
Average age	59	62
Living permanently on the holding, %	21	35
Occupation, %		
Wage earner	29	37
Farmer or forestry entrepreneur	4	9
Entrepreneur	9	6
Pensioner	56	47
Other (student, unemployed etc.)	4	2
Education		
No vocational education	15	28
Vocational education	23	27
College-level- or polytechnic degree	38	27
University degree	23	18
Yearly household income, %		
< 20 000 €	5	18
20 000 - 35 000 €	10	*
35 000 - 50 000 €	20	*
50 000 - 85 000 €	27	*
85 000 - 100 000 €	12	*
> 100 000 €	11	11
Forest land characteristics		
Average size, ha	50	48
Size of forest holding, %		
5-9,9 ha	15	16
10-19,9 ha	26	23
20-49,9 ha	29	33
50-99,9 ha	17	17
> 100 ha	13	12

* Different scale

In the core question of this analysis, the forest owners were asked to state their willingness to adopt 13 selected forest management practices that aim to promote biodiversity protection, climate change mitigation, or climate change adaptation in commercial forests. The list of forest management practices presented to forest owners was built in a workshop for forest professionals and researchers, organized in November 2018 by IBC-CARBON project. The aim of the workshop was, in order to serve scenario modeling, to identify the forest management practices that enhance carbon sequestration, carbon storage, and biodiversity conservation. Contemporary Tapio recommendations served as reference for the workshop. The question set was defined followingly: “Forest management decision affect timber production, carbon sequestration and storage, and biodiversity. How likely would you choose to carry out following forest management practices at your forest property?” The answers were given at 4-point scale including additional “I can’t say”, where 1=”definitely yes”, 2=”probably yes”, 3=”probably no”, 4=”definitely no” and 5=”I can’t say”. These forest management practices and descriptive statistics of responses are presented in Table 4. The forest management practices serve as dependent variables in the regression analysis.

Table 4 Respondent's likelihood to adopt suggested forest management practices



The likelihood to adopt forest management practices varied significantly. Broadleaved mixtures in coniferous forest, leaving retention trees, and saving game habitats were generally most accepted forest management practices among respondents; over 70% of respondents would “definitely” or “probably” adopt these measures to be conducted at their own forest property. Deadwood-related forest management practices (leaving at least 10m^3 of deadwood/ha when logging, leaving all harvest residues at the terrain, leaving maximum amount of wind-felled trees), continuous-cover forestry, increased growing density, and fertilization roughly divided opinions. Extending rotation period was least favored among respondents, as only 38% were likely to apply it on their forest property.

Regarding motivations of forest ownership, the respondents were asked to assess 16 statements. Answers were given at 5-point Likert-scale, where 5=”Very important” and 1=”Not at all important”. Simple data imputation (Allison, 2001) was applied for “I can’t say” responses (n=1-11 depending on the statement). These responses were recoded to equal 3 at 5-point Likert-scale. Motivation statements were used in principal component analysis and later as explanatory variables in the regression model.

4.2 Methods

In order to identify latent constructions among respondents’ motivations for their forest ownership, principal component analysis (PCA) with Varimax rotation was applied (e.g. Yong & Pearce, 2013). Components with eigenvalue greater than 1 were retained (Kaiser, 1960). Sampling adequacy of the data was assessed using Kaiser-Mayer-Olkin measure. To confirm the internal consistency of components, Cronbach’s alphas were evaluated (Tavakol & Dennick, 2011). The obtained principal components (the associated component scores) were used as explanatory variables in binary logistic regression models (Harrell, 2015).

In order to assess respondents’ willingness to adopt suggested forest management practices, binary logistic models were applied. Binary logit model was chosen over multinomial logit models, since differences between distinct forest management practices are more sensible to interpret through binary approach. For modeling purposes the survey data was modified. For dependent variables, “definitely yes” and “probably yes” answers were combined, and given value of 1. “Probably no” and “definitely no” responses were given value of 0. “I can’t say” responses were defined as missing values. Separate models were established for each distinct forest management practice included in the survey, forming a set of 13 distinct models.

To select relevant explanatory variables in the binary logistic regression model, a backward selection procedure was carried out (Bursac et al., 2008). One at the time, explanatory variables that were insignificant ($p > 0.05$) in all models were removed. The procedure was repeated until only relevant variables remained (p-value < 0.05 in at least one model). Explanatory variables in the initial model (see appendix 2) were based on the literature review of this thesis (see chapter 3.3). All variables that had been concluded statistically significant regarding forest owners' choice to adopt forest management practices were included in the initial model, on condition that such variables were available in the data. Additionally, factor scores from PCA of respondents' motivations were included as variables. A summary of variables used in the final binary logistic regression analysis is presented in Table 5.

Table 5
Variables used in binary logistic regression models

Variable name	Description	Min	Max	Mean	n
Dependent variables					
Buffer zones	Lighter managed buffer zones around important habitats and/or conservation areas	0	1	0,77	361
Deadwood	Leaving at least 10 m3 of deadwood per hectare when logging	0	1	0,69	374
Broadleaf mixtures	Mixed tree species in coniferous forest: at least one fifth of birches or other deciduous trees	0	1	0,83	378
Rentention trees	Leaving at least 5% of the logging volume as a stand (over 20 cm in diameter) E.g. keeping 10 m3/ha as a stand when logging 200 m3/ha	0	1	0,78	374
Wind-felled trees	Leaving wind-felled trees to the ground according to the maximum limit determined by the law of forest damage. Maximum limit for spruce is 10 m3/ha	0	1	0,57	377
Extended rotation	Lengthening the rotation period by a quarter (e.g. lengthening the regeneration cut from 80 to 100 years)	0	1	0,42	365
Harvest residues	Leaving all logging residues at the terrain (e.g. not harvested for bioenergy)	0	1	0,56	385
Game habitats	Saving habitats for game (e.g. thickets) at thinnings and tending of seedling stands	0	1	0,79	371
CCF	Continuous cover forestry (no clearcutting, soil preparation, or tree planting)	0	1	0,67	376
Increased density	Increasing growing density of the stand	0	1	0,68	364
Fertilization	Fertilizing low-yeilding areas	0	1	0,55	381
Shortened rotation	Shortening the rotation period by a quarter (e.g. shortening the regeneration cut from 80 years to 60 years)	0	1	0,53	362
Southern seedlings	Forest regeneration with southern seedlings that can adapt better to warming climate	0	1	0,50	366
Independent variables					
Age	Age of respondent in years	18	86	58,61	405
Size	Size of forest property in hectares	2	500	35,73	377
Income	Equals 1 if household income exceeds 50 000 annually, 0 otherwise	0	1	0,59	346
Edu	Equals 1 if respondent has university level or polytechnic degree, 0 otherwise	0	1	0,47	405
Fert man	Equals 1 if respondent applied fertilization during 2016-2018, 0 otherwise	0	1	0,12	405
Dit man	Equals 1 if respondent applied ditching during 2016-2018, 0 otherwise	0	1	0,18	405
Nat man	Equals 1 if respondent applied nature management during 2016-2018, 0 otherwise	0	1	0,16	405
Env mot	Component score for environmental motivation	-3,14	2,46	0,00	405
Imm mot	Component score for immaterial motivation	-3,66	2,65	0,00	405
Fin mot	Component score for financial motivation	-3,31	2,80	0,00	405
Emp mot	Component score for self-employment and outdoor activities motivation	-2,24	2,70	0,00	405

All statistical analysis were conducted using SPSS 26.

4.3 Results

4.3.1 Motivations of ownership

The results of PCA are presented in Table 6. Four principal components (PCs) extracted; environmental-, immaterial-, financial-, and self-employment & outdoor motivation. These components explained 67,7% of total variance (KMO=0.877, p=<0.001). Cronbach's alpha ranged between 0,80 and 0,88, indicating sufficient internal consistency of PC's. Environmental motivation consists of forest owner's ambitions to provide ecosystem services. Climate change mitigation, forest biodiversity protection, water protection, and air quality protection were all loaded strictly in environmental motivation. Immaterial motivation comprised of immaterial benefits and values related to forest ownership, such as relaxation, shared time with relatives and connection to home region. Also non-timber benefits such as berry/mushroom picking and wood for domestic use were included in this PC. Berry/mushroom picking were also cross-loaded in both environmental motivation (0,30) and self-employment & outdoor motivation (0,38), while relaxation (0,31) and shared time with relatives (0,32) were cross loaded in environmental motivation. Connection to home region was also cross-loaded in financial motivation. Financial motivation comprises of short- and long-term financial objectives related to forest ownership. Self-employment & outdoor motivation emphasizes business opportunities of one's own forest, and outdoor activities such as hunting at the forest property. This PC also included cross loadings (0.34-0.35) from financial motivations.

Table 6

PCA for motivations of forest ownership

Statement	Components			
	Environmental motivation	Immaterial motivation	Financial motivation	Self-employment and outdoor motivation
Financing major purchases and/or regular consuming			0,78	0,34
Financial security			0,81	
Investment, increase in value of forest stands			0,68	0,35
Income from work in own forest			0,51	0,65
Berry/mushroom picking at forest property	0,30	0,66		0,38
Hunting at forest property				0,73
Relaxation (outdoor acitivities, meditation, calming down)	0,31	0,72		
Forestry activities and/or wood for domestic use		0,68		
Shared time with family or relatives	0,32	0,71		
Bequest for relatives		0,47	0,59	
Connection to home region		0,59	0,41	
Other business opportunities at forest property (e.g. nature tourism)			0,35	0,72
Climate change mitigation	0,83			
Forest biodiversity protection	0,83			
Water protection through nutrient and sediment loading reduction	0,83			
Air quality protection through pollutant filtration	0,86			
Cronbach's alpha	0,88	0,81	0,83	0,80

Factor loadings below 0.300 not included

Kaiser-Mayer-Olkin measure of sampling adequacy 0.877, Bartlett's test for sphericity p=<0.001

4.3.2 Stated willingness to adopt forest management practices

The results of binary logistic regression analysis are presented in Table 7. Depending on the model 61.4-83.3% of responses were predicted correctly. Nagelkerke R^2 ranged between 0.06 and 0.32. Apparent reason for the considerable spread in R^2 values is the small amount of negative responses in some models with low R^2. Such problem occurred in *broadleaf mixtures*, *retention trees*, and *game thickets* models, as these models predicted only 3.9-12.7% of negative responses correctly, thus these models yielded low goodness of fit. However, low goodness of fit of *harvest residues, increased density,* and *southern seedlings* models were not explained by this reason. Otherwise, the model performance was considered sufficient. Sample size of models varied between 299 and 317.

Table 7
Binary logistic regression coefficients

	Variables												
Forest management practices	Age	Size	Income	Edu	Fert man	Dit man	Nat man	Env mot	Imm mot	Fin mot	Emp mot	Constant	Nagelkerke R^2
Buffer zones (n=299)	0,00	0,00	0,30	0,30	-0,15	-0,11	**1,04***	**0,63*****	0,13	**0,35***	-0,02	0,67	0,15
Deadwood (n=308)	**-0,03****	**-0,01***	-0,03	**0,75***	0,16	**-1,13****	**1,24****	**0,69*****	0,09	-0,15	-0,07	**2,72*****	0,25
Broadleaf mixtures (n=31	0,02(*)	0,00	-0,23	0,47	**1,70***	0,28	0,16	**0,42***	0,22	0,18	0,05	0,43	0,12
Rentention trees (n=312)	-0,01	-0,01(*)	0,15	0,29	0,16	-0,49	-0,18	**0,78*****	0,26(*)	-0,03	-0,08	**2,40*****	0,18
Wind-felled trees (n=310)	**-0,05*****	0,00	-0,01	**0,93****	0,21	-0,52	-0,21	**0,77*****	0,19	-0,13	-0,17	**3,01*****	0,28
Extended rotation (n=300	**-0,03*****	0,00	**0,84****	0,09	-0,34	-0,59(*)	0,03	**0,67*****	0,16	-0,22	-0,03	1,20(*)	0,23
Harvest residues (n=316)	**-0,02****	0,00	0,37	0,32	-0,15	0,21	0,63(*)	**0,27***	**0,27***	-0,08	-0,02	**1,26***	0,12
Game habitats (n=306)	0,01	0,00	-0,26	-0,07	-0,23	-0,01	0,85	**0,78*****	**0,32***	0,13	0,09	1,27(*)	0,17
CCF (n=317)	0,00	**-0,01****	0,27	-0,24	-0,12	-0,31	-0,55	**0,62*****	0,18	-0,21	**0,31***	**1,64***	0,20
Increased density (n=302	-0,01	0,00	0,05	-0,14	-0,01	-0,16	-0,04	0,23(*)	**0,33***	0,11	0,11	**1,35***	0,06
Fertilization (n=317)	-0,02	0,00	-0,22	-0,06	**2,18****	**1,17****	-0,34	0,16	**0,45****	**0,56*****	0,10	1,05(*)	0,31
Shortened rotation (n=30	-0,01	**-0,02****	-0,30	0,26	0,76(*)	0,29	-0,71(*)	**-0,28***	0,02	**0,65*****	**0,46****	1,03	0,23
Southern seedlings (n=30	0,00	0,00	-0,01	0,22	0,20	0,41	0,24	-0,01	0,07	**0,50*****	0,26(*)	0,16	0,12

(*), *, **, and *** indicate significance levels of 0.1, 0.05, 0.01, and 0.001, respectively

The effect of age was statistically significant (p=0,05) in four models; *deadwood, wind-felled trees, extended rotation,* and *harvest residues*. The sign of the coefficient was consistent in these models, increase in age decreased the probability to adopt forest management practices. Also increase in property size had negative effect in *deadwood*, *CCF,* and *shortened rotation* models. High income increased the probability to apply extended rotation. Highly educated forest owners were more likely to retain deadwood and wind-felled trees.

Three previous forest management practices were concluded statistically significant in some at least one model. Forest owners who had applied fertilization before, were more likely to adopt it also in the future. Previous ditching had a negative effect in *deadwood* model. The effect of previous nature management was positive in *buffer zones* and *deadwood* models.

Increase in environmental motivation (measured by a higher factor score) increased the probability to adopt most forest management practices assessed. At 5% significance level, positive effect occurred in *buffer zones, deadwood, broadleaf mixtures, retention trees, wind-felled trees, extended rotation, harvest residues, game habitats,* and *CCF* models. The coefficient of environmental motivation was negative in *shortened rotation*. Immaterial motivation had a positive effect in *harvest residues*, *game habitats, increased density*, and *fertilization* models. Financial motivation increased the probability to adopt *buffer zones*, *fertilization*, *shortened rotation*, and *southern seedlings*. Self-employment and outdoors motivation increased the probability to adopt *shortened rotation*.

5 Discussion

Principal component analysis yielded interpretable dimensions for motivations for forest ownership. Although some cross-loadings above 0,3 were recognized, the principal components seemed to represent distinct dimensions. Environmental motivation described forest owner's willingness to participate in environmental protection through their forest ownership. Immaterial motivation emphasized emotional attachments related to their own forest as well as psychological wellbeing provided by forest. Financial motivation captured both short-term and long-term financial benefits of forest ownership. Self-employment and outdoor activities motivation emphasized the importance of employment opportunities and recreational activities provided by one's own forest. Notably, very similar results were obtained in the FFO 2020 survey, where forest owners' objectives were analyzed using PCA and k-means clustering (Karppinen et al., 2020). Financial-, immaterial, and employment opportunities and outdoor dimensions were extracted with very similar factor loadings as in this study. The lack of environmental dimension distinguishes FFO 2020 results from this study. This could be explained by the fact that FFO 2020 survey included fewer statements regarding environmental objectives.

The results of the binary logistic regression analysis indicated that age, property size, education, income, previous management, and motivations of forest ownership affected willingness to adopt forest management practices. Statistically significant (p=0,1) coefficients of each explanatory variable had the same signs in different models, with the exception of previous ditching and nature management and environmental motivation. Some patterns could be recognized regarding statistical significance of variables over models. Increase in age reduced willingness to leave deadwood at harvest, allow wind-felled trees decay, leave harvest residues in the forest, and extend rotation period. All these forest management practices are related to increasing amount of deadwood in the forests. Therefore, this finding suggests that older owner might be reluctant towards deadwood retention in general. Concerning negative effect of age on willingness to extend rotation, the finding is consistent with Khanal et al. (2017) and Matta et al. (2009), but contrary to Juutinen et al. (2020). Slightly different research frame of Juutinen et al. (2020) might explain the contrary result: Juutinen et al. (2020) studied, what proportion of their land forest owners are willing to allocate under different management regimes. The reluctance towards deadwood retention measures and extended rotation might be associated to perceived threats of pest and pathogen invasions (Hysing & Olson 2005; Joa & Schraml, 2020) and the worry of decaying timber if harvest is postponed (Karppinen et al., 2018). High income increased probability to extend rotation. Possibly, wealthy forest owners might not be in a hurry to realize profits from final felling. Consistently with Joa & Scraml (2020), high education yielded contrary effects to age in deadwood and wind-felled trees models, indicating that highly educated forest owners might have generally positive attitudes towards deadwood retention. The effect of property size on willingness to adopt forest management practice was generally negative, but no apparent patterns for occurrence of statistically significant effects were recognized.

In terms of previous management, the results from binary logistic regression were somewhat expected. Previous fertilization and ditching increased the probability to adopt fertilization. These are both rather expensive management practices that aim to increase the productivity of the forest site. Since ditching typically causes strain on water systems, negative coefficients were expected for environmentally beneficial forest management practices. Negative coefficient of ditching was statistically significant also in deadwood model. Previous nature management yielded positive coefficients for buffer zones and deadwood. At 10% significance level, the effect was positive also for harvest residues and negative for shortened rotation. Since effect of environmental motivation was statistically significant in 10 models, it is somewhat peculiar that previous nature management was statistically significant in only two models. This might result from possible data deficiency; only 16% of survey respondents stated that they had conducted nature management activities such as leaving snags, retention trees, or riparian buffers. This result seem odd, since approximately 90% of Finland’s commercial forests are PEFC-certified, and leaving retention trees is required by certification.

The effects of ownership motivations on willingness to adopt forest management practices were rather consistent. Environmental motivation had a positive effect on almost all forest management practices assessed in this study. The negative coefficient of environmental motivation in shortened rotation model also seems consistent, since shortened rotation potentially has negative implications for biodiversity (Ranius et al., 2003; Mönkkönen et al., 2014; Felton et al., 2016). This result suggests that environmentally motivated forest owners might be willing to accept a variety forest management practices to be conducted in their forests to provide environmental benefits, but not those measures that potentially conflict with biodiversity. Consistency was also be recognized in the effect of financial motivation, as it increased the probability to adopt fertilization, shortened rotation, and use of southern seedlings in regeneration. These forest management do not necessarily contradict with economically optimal timber production, rather they may promote it. Financial motivation also increased the probability to adopt lighter managed buffer zones around protected areas. The result is somewhat surprising, since adopting such forest management practice might not be economically optimal. The effects of immaterial motivation and self-employment and outdoor activities motivation on willingness to adopt forest management practices were not as straightforward. The effects of immaterial motivation were similar to environmental motivation as positive statistically significant ($p<0,05$) coefficients were obtained in harvest residues, game habitats, but also in fertilization models. Self-employment and outdoor activities motivation increased the probability to adopt continuous cover forestry and shorten rotation.

As shown in Table 4, forest owners were not indifferent in terms of what forest management they are willing to conduct in their forests, but willingness to adopt varied greatly between forest management practices. Possible explanations for the variation could be perceived benefits and threats, economical aspects, familiarity of forest management practices, feasibility, and easiness of implementation. Broadleaved mixtures was most favored forest management practices in the study. Possibly, forest owners perceive benefits such as increased resilience towards risks induced by climate change, and are therefore willing to adopt broadleaved mixtures in their forests. Favorable attitudes towards retention trees could be explained by the fact that this practice is required by PEFC certification, and might therefore be familiar for most forest owners. Previous literature also reports favorable attitudes towards broadleaved mixtures and retention trees: according to Vedel et al. (2015); Danish forest owners might adopt these forest management practices with very little or no compensation. Concerning deadwood retention, Joa & Schraml (2020) concluded that perceived hazards and benefits affected forest owners' willingness to retain deadwood, and Hysing & Olson (2005) reported perceived risks towards pest and pathogen invasions as well as perception of leaving deadwood being contrary to established image of a well-managed forest. Skepticism towards extended rotation could be explained by worry of pest and pathogen invasions and perceived economic disadvantages.

The results of binary logistic regression were not fully consistent with previous literature. The effect of gender, residence on forest property, membership in forest owners' association and previous regeneration management actions were concluded insignificant in this analysis, although previous literature suggests that women, resident forest owners, and non-members of forest owners' association are more likely to adopt forest management practices promoting carbon sequestration (Matta et al., 2009; Danley, 2018; Juutinen et al., 2020). Insignificant effect of previous forest regeneration seems comprehensible, since forest regeneration is regulated by law in Finland. Despite these minor differences with previous research, consistency in signs of statistically significant coefficients and recognized patterns (e.g. effect of age on deadwood, consistent effect of environmental motivation) suggest that the effects of variables are not randomly generated, but real.

Few issues need to be acknowledged considering reliability of the results. Comparison of forest owner characteristics with the FFO 2020 survey indicated that the data was slightly biased towards younger forest owners and city-dwellers. It is possible that the bias affected the results of empirical analysis. However, similarities in the results of PCA with FFO 2020 survey increase the credibility of the data. Some of regression models yielded low values for goodness of fit. This could be explained by the small amount of negative responses in models considering most favored forest management practices (broadleaved mixtures, game habitats, retention trees), but not for harvest residues (Nagelkerke R^2 = 0.12), increased density (Nagelkerke R^2 = 0.06), southern seedlings (Nagelkerke R^2 = 0.12). Therefore, the results of these models need to be approached with reservations. Additionally, the empirical analysis was based on stated intention to adopt forest management practices. When it comes to stated preference survey techniques, hypothetical bias between stated and revealed commitment of respondents can occur. In non-market valuation, individuals are typically believed to overstate their economic valuation (Murphy et al., 2005). However, in case of this survey, an obvious incentive for respondents to over- or understate likelihood to adopt forest management practices does not seem to exist. In case compensation claims for adoption of forest management practices had been assessed, hypothetical bias could have been a greater issue.

It is important to note that the statistical analysis conducted in this thesis does not account for compensation claims or contract terms. Since forest owners' management decisions are often considered to be based on utility-maximizing behavior, it is reasonable to assume that they generally claim compensation for adopting forest management practices that contradict with economically optimal forestry. The results of this study suggests that environmental motivation increases probability to adopt a variety of such forest management practices. However, a question remains whether these environmentally motivated forest owners would actually conduct economically conflicting forest management practices in their forests without monetary compensation. Previous research suggests that even though willingness to adopt measures to safeguard biodiversity or promote carbon sequestration might be partially value-driven, the vast majority of forest owners require compensation for economically conflicting forest management practices (Koskela & Karppinen, 2020; Khanal et al., 2017).

As suggestion for future research, there seems to be a need to further examine forest owners' views towards distinct forest management practices that aim to promote carbon sequestration, climate change adaptation, or biodiversity protection. The results of this study suggest that willingness to adopt measures greatly varies between different forest management practices, but the question remains what explains these differences. A qualitative approach could be utilized to discover forest owners' perceived benefits and disadvantages related to different forest management practices. Additionally, an empirical analysis assessing forests owners' compensation claims related different forest management practices would provide useful knowledge for policy makers aiming to further climate change mitigation, climate change adaptation, and biodiversity conservation in commercial forests. When it comes to implementing such policies, environmentally motivated forest owners seem like a potential target group, especially for biodiversity conservation and carbon sequestration. However, further research is needed to identify environmentally motivated forest owners.

6 Conclusions

In this thesis, a systematic literature review and an empirical analysis were conducted to examine what factors affect NIPF owners willingness to adopt various forest management practices that aim to promote carbon sequestration, climate change adaptation, or biodiversity in commercial forests. Additionally, this thesis examined how these factors differ among distinct forest management practices. The results suggest that willingness to adopt forest management practices is associated with sociodemographic characteristics, site-specific characteristics, previous management actions, and owner motivations, but the occurrence of these factors varied among different forest management practices. Additionally, forest owners were not indifferent in terms of what forest management practices they were willing to conduct in their forest, but willingness to adopt forest management practices varied greatly.

Previous research has showed that forest owners are a diverse group, and they have varying objectives and motivations for their ownership. The results of this study imply that forest owner diversity shows also in their willingness to adopt forest management practices. An important finding of the thesis is that motivations of forest ownership seem to guide their management behavior: forest owners are willing to adopt forest management practices consistent with their motivations, and reluctant towards conflicting practices. In this study, especially the association of environmental and financial motivations with willingness to adopt forest management practices stood out. However, the question whether motivations of forest ownership affect compensation claims associated to adopting economically conflicting forest management practices remains as suggestion for further research.

When promoting carbon sequestration, climate change adaptation, or biodiversity conservation in commercial forests through policies and advisory services, more focus needs to be put on forest management practices that are applied to contribute to these objectives, since forest owners' willingness to adopt forest management practices that aim to promote these objectives vary between different measures. There seems to be need especially for further research on attitudinal aspects that affect forest owners' willingness to adopt different forest management practices. Knowledge of forest owners' perceived benefits and threats considering distinct forest management practices would be valuable in educating forest owners through advisory services such as TAPIO recommendations. Regarding policies aiming to promote carbon sequestration, climate change adaptation, or biodiversity conservation in commercial forests, previous literature has acknowledged importance of targeting policies to forest owners whose objectives and views are consistent with these objectives. The results of this thesis emphasize importance of incorporating consideration what forest management practices would be applied to achieve these objectives when designing and implementing policies.

References

Allison, P. D. (2001). Missing data. *Sage University Papers Series on Quantitative Applications in the Social Sciences, 07-136*

Binkley, C. (1981). Timber Supply From Private Nonindustrial Forests. *Yale School of Forestry & Environmental Studies Bulletin Series. 7.*

Brockerhoff, E. G., Barbaro, L., Castagneyrol, B., Barbaro, L, Castagneyrol, B., Forrester, D. I., Gardiner, B., Gonzalez-Olabarria, J. R., Lyver, P. O., Meurisse, N., Oxborough, A., Hisatomo, T., Thompson, I. D., van der Plas, F., Jactel, H. (2017). Forest biodiversity, ecosystem functioning and the provision of ecosystem services. *Biodiversity and Conservation, 26* (13), 3005–3035. https://doi.org/10.1007/s10531-017-1453-2

Bursac, Z., Gauss, C. H., Williams, D. K., & Hosmer, D. W. (2008). Purposeful selection of variables in logistic regression. *Source code for biology and medicine, 3*(1), 17.

Butler, Brett J.; Hewes, Jaketon H.; Dickinson, Brenton J.; Andrejczyk, Kyle; Butler, Sarah M.; Markowski-Lindsay, Marla. 2016. USDA Forest Service National Woodland Owner Survey: national, regional, and state statistics for family forest and woodland ownerships with 10+ acres, 2011-2013. *Res. Bull. NRS-99. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station.*

Danley, B. (2018). Skepticism of state action in forest certification and voluntary set-asides: a Swedish example with two environmental offsetting options. *Scandinavian Journal of Forest Research, 33*(7), 695-707.

Danley, B. (2019). Forest owner objectives typologies: Instruments for each owner type or instruments for most owner types?. *Forest Policy and Economics, 105*, 72-82.

Egan, A. F. (1997). From Timber to Forests and People: A View of Nonindustrial Private Forest Research. *Northern Journal of Applied Forestry, 14*(4), 189-193.

Felton, A., Gustafsson, L., Roberge, J. M., Ranius, T., Hjältén, J., Rudolphi, J., ... & Felton, A. M. (2016). How climate change adaptation and mitigation strategies can threaten or enhance the biodiversity of production forests: Insights from Sweden. *Biological Conservation, 194*, 11-20.

Ficko, A., Lidestav, G., Dhubhain, A. N., Karppinen, H., Zivojinovic, I., & Westin, K. (2019). European private forest owner typologies: A review of methods and use. *Forest Policy and Economics, 99*, 21-31.

FSC Suomi. (2011). Suomen FSC-standardi. Retrieved from https://fi.fsc.org/fi-fi/sertifiointi/metssertifiointi/suomen-fsc-standardi

FOREST EUROPE, 2015: State of Europe’s Forests 2015. Retrieved from https://foresteurope.org/state-europes-forests-2015-report/

FSC Suomi. (2019). Toimintakertomus 2019. Retrieved from https://fi.fsc.org/fi-fi/tietoa-fscst/suomen-fsc

Götmark, F., Söderlundh, H., & Thorell, M. (2000). Buffer zones for forest reserves: opinions of land owners and conservation value of their forest around nature reserves in southern Sweden. *Biodiversity & Conservation, 9*(10), 1377-1390.

Hallikainen, V., Hyppönen, M., Pernu, L., & Puoskari, J. (2010). Family forest owners' opinions about forest management in northern Finland. *Silva Fennica, 44*(2).

Harrell Jr, F. E. (2015). *Regression modeling strategies: with applications to linear models, logistic and ordinal regression, and survival analysis.* Springer series in statistics, 0172-7397. Springer.

Horne, P. (2006). Forest owners' acceptance of incentive based policy instruments in forest biodiversity conservation-A choice experiment based approach. *Silva Fennica, 40*(1).

Hysing, E., & Olsson, J. (2005). Sustainability through good advice? Assessing the governance of Swedish forest biodiversity. *Environmental Politics, 14*(4), 510-526.

Hyvärinen, E., Juslén, A., Kemppainen, E., Uddström, A. & Liukko, U.-M. (toim.) 2019. Suomen lajien uhanalaisuus – *Punainen kirja 2019. Ympäristöministeriö & Suomen ympäristökeskus. Helsinki.* 704 s.

Joa, B., Schraml, U. (2020). Conservation practiced by private forest owners in Southwest Germany – The role of values, perceptions and local forest knowledge. *Forest Policy and Economics, 115,* art. no. 102141.

Joensuu, S., Kauppila, M., Lindén, M. & Tenhola, T. 2019. Metsänhoidon suositukset vesiensuojeluun, työopas. *Tapion julkaisuja*.

Joshi, S., & Arano, K. (2009). Determinants of private forest management decisions: A study on West Virginia NIPF landowners. *Forest Policy and Economics, 11*(2), 118–125.

Juutinen, A., Tolvanen, A., & Koskela, T. (2020). Forest owners’ future intentions for forest management. *Forest Policy and Economics,* 118.

Kaiser, H. F. (1960). The application of electronic computers to factor analysis. *Educational and psychological measurement, 20*(1), 141-151.

Kang, M. J., Siry, J. P., Colson, G., & Ferreira, S. (2019). Risk Attitudes and Conservation Decisions: A Case Study of Family Forest Owners in Georgia. *Forest Science, 65*(2), 201-210.

Karppinen, H., Hänninen, M., & Valsta, L. (2018). Forest owners’ views on storing carbon in their forests. *Scandinavian Journal of Forest Research, 33*(7), 708-715.

Karppinen, H, Hänninen, H. & Horne, P. (2020). Suomalainen metsänomistaja 2020. *Luonnonvara- ja biotalouden tutkimus 30/2020.* Luonnonvarakeskus. Helsinki. 73 s.

Kellomäki, S., Strandman, H., Heinonen, T., Asikainen, A., Venäläinen, A., & Peltola, H. (2018). Temporal and spatial change in diameter growth of boreal Scots pine, Norway spruce, and birch under recent-generation (CMIP5) global climate model projections for the 21st century. *Forests, 9*(3), 118.

Khanal, P., Grebner, D., Munn, I., Grado, S., Grala, R., & Henderson, J. (2017). Evaluating non-industrial private forest landowner willingness to manage for forest carbon sequestration in the southern United States. *Forest Policy and Economics*, *75*, 112–119.

Kim, T., & Langpap, C. (2015). Incentives for carbon sequestration using forest management. *Environmental and Resource Economics*, *62*(3), 491-520.

Kline, J. D., Alig, R. J., & Johnson, R. L. (2000a). Fostering the production of nontimber services among forest owners with heterogeneous objectives. *Forest Science, 46*(2), 302-311.

Kline, J. D., Alig, R. J., & Johnson, R. L. (2000b). Forest owner incentives to protect riparian habitat. *Ecological Economics, 33*(1), 29-43.

Koskela, E., Ollikainen, M., & Pukkala, T. (2007). Biodiversity policies in commercial boreal forests: optimal design of subsidy and tax combinations. *Forest Policy and Economics, 9*(8), 982-995.

Koskela, T., & Karppinen, H. (2020). Forest Owners' Willingness to Implement Measures to Safeguard Biodiversity: Values, Attitudes, Ecological Worldview and Forest Ownership Objectives. *Small-scale Forestry, 1-27.*

Kooistra, C. M., Moseley, C., Huber-Stearns, H., & Rosenberg, S. (2018). Western Oregon forest landowner beliefs about the outcomes of mandatory riparian buffer regulations. *Journal of Sustainable Forestry, 37*(1), 56-76.

Lindén, M., Lilja-Rothsten, S., Saaristo, L. & Keto-Tokoi, P. 2019. (toim.) Metsänhoidon suositukset riistametsänhoitoon, työopas. *Tapion julkaisuja.*

Markowski-Lindsay, M., Stevens, T., Kittredge, D., Butler, B., Catanzaro, P., & Dickinson, B. (2011). Barriers to Massachusetts forest landowner participation in carbon markets. *Ecological Economics*, *71*, 180–190.

Matta, J., Alavalapati, J., & Mercer, D. (2009). Incentives for Biodiversity Conservation Beyond the Best Management Practices: Are Forestland Owners Interested? *Land Economics, 85*(1), 132–143.

METSO – The Forest Biodiversity Programme for Southern Finland. (2019). METSO Fact Sheet Retrieved from https://metsonpolku.fi/en-US/Materials

Ministry of Agriculture and Forestry. (Published 02.04.2020). Metsien tuhkalannoituksen tuki laajenee, valtioneuvosto hyväksyi asetusmuutoksen [Announcement]. Retrieved from https://valtioneuvosto.fi/-/1410837/metsien-tuhkalannoituksen-tuki-laajenee-valtioneuvosto-hyvaksyi-asetusmuutoksen

Ministry of Agriculture and Forestry. 2019. Kansallinen metsästrategia 2025 – päivity. Valtioneuvoston periaatepäätös 21.2.2019. *Maa- ja metsätalousministeriön julkaisuja* 2019:7.

Murphy, J. J., Allen, P. G., Stevens, T. H., & Weatherhead, D. (2005). A meta-analysis of hypothetical bias in stated preference valuation. *Environmental and Resource Economics*, *30*(3), 313-325.

Mäntymaa, E., Ovaskainen, V., Juutinen, A., & Tyrväinen, L. (2018). Integrating nature-based tourism and forestry in private lands under heterogeneous visitor preferences for forest attributes. *Journal of Environmental Planning and Management*, *61*(4), 724-746.

Mönkkönen, M., Juutinen, A., Mazziotta, A., Miettinen, K., Podkopaev, D., Reunanen, P., ... & Tikkanen, O. P. (2014). Spatially dynamic forest management to sustain biodiversity and economic returns. *Journal of Environmental Management*, *134*, 80-89.

PEFC Suomi. (2014). PEFC-metsäsertifioinnin kriteerit. PEFC FI 1002:2014. Retrieved from https://pefc.fi/palvelut/standardit/

PEFC Suomi. (2020). Vuosijulkaisu 2019. Retrieved from https://pefc.fi/palvelut/materiaalit/

Peltola, A., Ihalainen, A., Mäki-Simola, E., Sauvula-Seppälä, T., Torvelainen, J., Uotila, E., Vaahtera, E. & Ylitalo, E. (2019). Suomen Metsätilastot—Finnish Forest Statistics. Luke Natural Resources Institute Finland: Helsinki, Finland, 200.

Pihlainen, S., Tahvonen, O., & Niinimäki, S. (2014). The economics of timber and bioenergy production and carbon storage in Scots pine stands. *Canadian Journal of Forest Research, 44*(9), 1091-1102.

Pynnönen, S., Paloniemi, R., & Hujala, T. (2018). Recognizing the interest of forest owners to combine nature-oriented and economic uses of forests. *Small-scale Forestry*, *17*(4), 443-470.

Rametsteiner, E., & Simula, M. (2003). Forest certification—an instrument to promote sustainable forest management?. *Journal of environmental management*, *67*(1), 87-98.

Ranius, T., Kindvall, O., Kruys, N., & Jonsson, B. G. (2003). Modelling dead wood in Norway spruce stands subject to different management regimes. *Forest Ecology and management*, *182*(1-3), 13-29.

Saaristo, L. & Vanhatalo, K. (toim.) 2019. Metsänhoidon suositukset talousmetsien luonnonhoitoon, työopas. *Tapion julkaisuja.*

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. *International journal of medical education, 2*(53).

Thompson, D., & Hansen, E. (2012). Factors Affecting the Attitudes of Nonindustrial Private Forest Landowners Regarding Carbon Sequestration and Trading. *Journal of Forestry, 110*(3), 129–137.

Thompson, I., Mackey, B., McNulty, S., & Mosseler, A. (2009). Forest resilience, biodiversity, and climate change. In Secretariat of the Convention on Biological Diversity, Montreal. *Technical Series no. 43. 1-67.* (Vol. 43, pp. 1-67).

Valtioneuvosto, 2019. Osallistava ja Osaava Suomi – sosiaalisesti, taloudellisesti ja ekologisesti kestävä yhteiskunta. Pääministeri Antti Rinteen hallituksen ohjelma 6.6.2019. *Valtioneuvoston julkaisuja 2019:*23

Van Herzele, A., & Van Gossum, P. (2009). Owner-specific factors associated with conversion activity in secondary pine plantations. *Forest Policy and Economics, 11*(4), 230-236.

Vedel, S. E., Jacobsen, J. B., & Thorsen, B. J. (2015). Forest owners' willingness to accept contracts for ecosystem service provision is sensitive to additionality. *Ecological Economics, 113,* 15-24.

Venäläinen, A., Lehtonen, I., Laapas, M., Ruosteenoja, K., Tikkanen, O. P., Viiri, H., ... & Peltola, H. (2020). Climate change induces multiple risks to boreal forests and forestry in Finland: A literature review. *Global change biology, 26*(8), 4178-4196.

Yong, A. G., & Pearce, S. (2013). A beginner’s guide to factor analysis: Focusing on exploratory factor analysis. *Tutorials in quantitative methods for psychology, 9*(2), 79-94.

Äijälä, O., Koistinen, A., Sved, J., Vanhatalo, K. & Väisänen, P. (toim.) 2019. Metsänhoidon suositukset. *Tapion julkaisuja.*

Appendices

Appendix 1

Search terms for literature review

Search terms	# results in SCOPUS	Search terms (continued	# results in SCOPUS
"forest owner*" AND leng*	54	forest* AND "land owner*" AND delay*	4
"forest owner*" AND delay*	13	forest* AND "land owner*" AND extend*	23
"forest owner*" AND extend*	52	forest* AND "land owner*" AND forego*	1
"forest owner*" AND forego*	6	forest* AND "land owner*" AND fertiliz*	10
"forest owner*" AND fertiliz*	18	forest* AND "land owner*" AND decay*	2
"forest owner*" AND decay*	12	forest* AND "land owner*" AND residues*	5
"forest owner*" AND residues*	35	forest* AND “land owner*” AND wind-felled*	0
“forest owner*” AND wind-felled*	3	forest* AND “land owner*” AND "wind felled*"	0
“forest owner*” AND "wind felled*"	3	forest* AND “land owner*” AND bioenergy*	21
“forest owner*” AND bioenergy*	61	forest* AND “land owner*” AND "continuous cover*"	1
“forest owner*” AND "continuous cover*"	11	forest* AND “land owner*” AND "continuous-cover*"	1
“forest owner*” AND "continuous-cover*"	11	forest* AND “land owner*” AND "uneven age*"	0
“forest owner*” AND "uneven age*"	20	forest* AND “land owner*” AND uneven-age*	0
“forest owner*” AND uneven-age*	20	forest* AND “land owner*” AND mix*	46
“forest owner*” AND mix*	101	forest* AND “land owner*” AND broad-lea*	3
“forest owner*” AND broad-lea*	12	forest* AND “land owner*” AND birch*	1
“forest owner*” AND birch*	19	forest* AND “land owner*” AND aspen*	2
“forest owner*” AND aspen*	4	forest* AND “land owner*” AND *habitat*	133
“forest owner*” AND *habitat*	114	forest* AND “land owner*” AND "dense area*"	0
“forest owner*” AND "dense area*"	0	forest* AND “land owner*” AND *density*	73
“forest owner*” AND *density*	84	forest* AND “land owner*” AND *rotation* AND *shorten*	0
“forest owner*” AND *rotation* AND *shorten*	4	forest* AND "land owner*" AND stated*	5
"forest owner*" AND stated*	27	forest* AND "land owner*" AND "behavio* intention"	1
"forest owner*" AND "behavio* intention"	7	forest* AND *owner* AND retention	99
forest* AND owner* AND carbon*	424	forest* AND *owner* AND shorten*	30
forest* AND owner* AND biodiv*	612	forest* AND *owner* AND burn*	205
forest* AND "land owner*" AND leng*	21	forest* AND *owner* AND invasive*	155

Total: 2569

Appendix 2

Initial binary logistic regression model coefficients

Forest management practices (*Variables*)	Age	Gender	Property size	Resident	Second residence	High income	High education	Member in forest owners' association	Regeneration management	Fertilization	Ditching	Nature management	Environmental motivation	Immaterial motivation	Financial motivation	Self-emp. and outdoor activities motivation	Constant	Nagelkerke R2
Buffer zones	0,004	-0,359	-0,002	0,364	0,055	0,344	0,298	0,347	0,122	-0,173	-0,129	**1,047**	**0,609**	0,068	0,284	-0,010	0,563	0,167
	(0,717)	(0,302)	(0,460)	(0,391)	(0,870)	(0,297)	(0,377)	(0,285)	(0,713)	(0,725)	(0,745)	(0,038)	(0,000)	(0,674)	(0,104)	(0,956)	(0,433)	
Deadwood	**-0,029**	0,010	**-0,007**	0,217	0,238	-0,009	**0,762**	-0,185	-0,376	0,252	**-1,077**	**1,241**	**0,691**	0,109	-0,109	-0,104	2,760	0,257
	(0,008)	(0,975)	(0,023)	(0,568)	(0,459)	(0,978)	(0,016)	(0,564)	(0,242)	(0,608)	(0,003)	(0,006)	(0,000)	(0,497)	(0,532)	(0,539)	(0,000)	
Broadleaf mixtures	0,015	0,129	-0,005	0,825	0,532	-0,234	0,564	-0,265	-0,006	**1,810**	0,229	0,037	**0,427**	0,111	0,169	-0,024	0,431	0,145
	(0,190)	(0,726)	(0,115)	(0,099)	(0,158)	(0,516)	(0,125)	(0,465)	(0,987)	(0,022)	(0,619)	(0,939)	(0,014)	(0,543)	(0,383)	(0,903)	(0,557)	
Rentention trees	-0,017	0,242	**-0,006**	**0,916**	0,431	0,190	0,430	-0,548	-0,082	0,304	-0,494	-0,327	**0,831**	0,193	-0,039	-0,176	2,537	0,209
	(0,152)	(0,499)	(0,022)	(0,045)	(0,244)	(0,573)	(0,210)	(0,135)	(0,819)	(0,554)	(0,201)	(0,440)	(0,000)	(0,282)	(0,839)	(0,347)	(0,001)	
Wind-felled trees	**-0,048**	-0,396	0,000	0,003	0,556	-0,080	**0,891**	-0,019	0,093	0,268	-0,464	-0,195	**0,735**	0,108	-0,104	-0,186	3,010	0,296
	(0,000)	(0,194)	(0,985)	(0,993)	(0,074)	(0,783)	(0,003)	(0,950)	(0,757)	(0,583)	(0,181)	(0,595)	(0,000)	(0,479)	(0,519)	(0,255)	(0,000)	
Extended rotation	**-0,037**	0,289	0,002	**0,761**	0,112	**0,915**	0,219	0,012	-0,476	-0,271	-0,579	-0,086	**0,718**	0,186	-0,231	-0,118	1,174	0,257
	(0,000)	(0,329)	(0,497)	(0,041)	(0,704)	(0,002)	(0,456)	(0,968)	(0,112)	(0,534)	(0,104)	(0,816)	(0,000)	(0,222)	(0,154)	(0,457)	(0,068)	
Harvest residues	**-0,027**	0,368	-0,001	0,508	0,061	0,390	0,429	-0,250	-0,094	-0,046	0,180	0,519	**0,280**	**0,275**	-0,084	-0,068	1,261	0,144
	(0,004)	(0,179)	(0,770)	(0,137)	(0,828)	(0,147)	(0,118)	(0,360)	(0,732)	(0,912)	(0,590)	(0,149)	(0,036)	(0,048)	(0,562)	(0,641)	(0,038)	
Game habitats	0,004	**0,749**	0,001	-0,109	-0,570	-0,272	0,050	0,344	0,108	-0,344	-0,161	0,796	**0,885**	**0,391**	0,091	0,132	0,949	0,206
	(0,729)	(0,034)	(0,828)	(0,822)	(0,118)	(0,454)	(0,892)	(0,314)	(0,762)	(0,509)	(0,716)	(0,146)	(0,000)	(0,027)	(0,635)	(0,500)	(0,209)	
CCF	-0,002	-0,266	**-0,013**	0,421	0,067	0,363	-0,256	-0,078	-0,384	-0,071	-0,241	-0,541	**0,619**	0,198	-0,202	0,285	1,833	0,215
	(0,877)	(0,384)	(0,005)	(0,270)	(0,824)	(0,213)	(0,387)	(0,795)	(0,212)	(0,875)	(0,485)	(0,136)	(0,000)	(0,192)	(0,236)	(0,075)	(0,006)	
Increased density	-0,011	0,196	0,000	0,015	0,187	-0,005	-0,098	0,300	0,211	-0,044	-0,235	-0,083	0,245	0,277	0,083	0,106	1,092	0,077
	(0,287)	(0,513)	(0,891)	(0,968)	(0,538)	(0,986)	(0,741)	(0,295)	(0,468)	(0,922)	(0,513)	(0,822)	(0,083)	(0,060)	(0,586)	(0,497)	(0,092)	
Fertilization	-0,018	0,152	-0,004	-0,077	0,181	-0,243	-0,053	0,472	-0,302	**2,192**	**1,155**	-0,308	0,196	**0,478**	**0,589**	0,090	0,882	0,328
	(0,088)	(0,603)	(0,227)	(0,834)	(0,553)	(0,395)	(0,853)	(0,104)	(0,301)	(0,001)	(0,002)	(0,402)	(0,170)	(0,002)	(0,000)	(0,568)	(0,175)	
Shortened rotation	-0,005	-0,081	**-0,017**	0,297	0,139	-0,269	0,266	-0,137	-0,124	0,823	0,340	**-0,749**	**-0,296**	0,008	**0,659**	**0,442**	1,085	0,238
	(0,615)	(0,777)	(0,001)	(0,401)	(0,635)	(0,341)	(0,354)	(0,628)	(0,666)	(0,075)	(0,337)	(0,043)	(0,034)	(0,955)	(0,000)	(0,005)	(0,099)	
Southern seedlings	-0,003	-0,406	-0,001	-0,029	-0,166	0,039	0,148	-0,171	0,281	0,209	0,426	0,249	-0,044	0,045	**0,473**	**0,302**	0,344	0,135
	(0,730)	(0,143)	(0,653)	(0,932)	(0,557)	(0,886)	(0,592)	(0,534)	(0,307)	(0,621)	(0,198)	(0,471)	(0,742)	(0,743)	(0,001)	(0,041)	(0,566)	

Note: Statistically significant coefficients bolded (p=0.05), p-values reported in parentheses